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Physical Properties of Active Comets

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Research Summary

This research consisted of an intensive observational study of the morphology and photometry of selected active comets. The study was intended to clarify the variation of the morphology and photometry with respect to time, and to produce robust quantitative information on the temporal and morphological properties of the inner coma. The strongest constraints on the nature of comets are those obtained from incisive observations of end-member examples. Hence, we have concentrated on comets active at large distances from the sun (to learn about outgassing and coma formation by super-volatiles), on split comets (to learn about the structural properties of the nucleus and the splitting mechanism) and on transition objects including the ice-rich centaurs and Jovian Trojans. While not classically regarded as comets, it is now widely recognized that the latter objects are probably precursors and cousins, respectively, of the active comets observed nearer the sun. This research exploited new large-format optical charge-coupled device (CCD) and infrared detectors and the high-quality seeing at the Mauna Kea Observatories.

- We undertook a critical review of the comet-asteroid relation (Jewitt 1995). Our main result is that, while the observational difference between comets and asteroids is clear enough (being based on the presence or absence of a coma), the more important physical distinction is blurred. We do not possess the means to determine the ice fraction in the small bodies of the solar system, unless (like the comets) they fortuitously pass close enough to the sun to sublimate the ice. Thus, the Trojan asteroids of Jupiter, which we have studied spectroscopically in the optical and near-infrared, may be internally ice-rich ("comets"), but we have no way to determine this from remote observation. The debate about the cometary vs. asteroidal nature of P/Shoemaker-Levy 9 reflects this ambiguity in the physical (as opposed to observational) classification of small bodies. The importance of this result is that we should not focus observational attention too heavily on one class of small bodies, because it is likely that many classes are inter-related, and that we can learn more from synthesized observations of objects in different groups.

- We performed a systematic analysis of our CCD data archive with the purpose of determining the rate at which comets split. The result is a splitting probability of order

$$\mathfrak{R} = 10^{-2} \text{ [per year per comet]}$$

(Chen and Jewitt 1994). Coupled with the $\tau \sim 10^5$ yr dynamical lifetime of the short-period comets, this result suggests that each comet splits roughly $\mathfrak{R} * \tau \sim 10^3$ times. Clearly, this would only be possible if splitting involves the release of small fragments of the parent nucleus, rather than the actual breaking of the nucleus into equal-sized pieces. That this is likely to be so, in the general case, is evident in the rapid fading of the secondary components of most (but not all) split comets.

We feel that the essential correctness of the derived splitting rate is confirmed by observations of numerous newly split comets since the publication of our paper (e.g. Shoemaker-Levy 9, Machholz, Schwassmann-Wachmann 3). Physical observations of these split comets (CCD images, surface brightness maps, color maps) have been acquired, and are under study. The observations are being used to understand the processes by which cometary fragments die. Rather than a simple loss of volatiles leading to coma production shut-down, we find evidence for complete disintegration of the fragments. The appropriate model seems to be one in which ices act as glue to hold the fragments together. When the ice is depeleted, the fragment loses all structural coherence, and appears in our imaging data as a diffuse smudge. The observations may also be compatible with the swarm model previously proposed.

- We continued to monitor 2060 Chiron at distance $R \sim 9$ AU (Luu and Jewitt 1993). This object is the largest of the known Centaurs (dynamically short-lived objects in the vicinity of the gas giant planets) and the only one known to display cometary activity. It is especially significant in its likely role as a recently dislodged member of the Kuiper Belt. We measured the coma surface brightness profile and total magnitude. The new measurements show that this body is weakly but continually active, even though its surface is too cold for water ice to sublimate. Deep integrations on the 230 GHz CO[2-1] rotational transition with the James Clerk Maxwell Telescope failed to show evidence for outgassing CO. The limit on the CO mass production rate is ~200 kg/s, which is not sufficient to eliminate CO as the driver of observed activity in Chiron.

- We obtained near-infrared spectra of selected active comets and related objects using the CGS4 spectrometer on the United Kingdom Infra-Red Telescope (UKIRT). These spectra were obtained in an attempt to identify surface materials on the embedded nuclei, and in the dust comae of these comets. Our first paper (Luu, Jewitt and Cloutis 1994) presents results for the inactive objects in our sample. The only features identified were those in Centaur 5145 Pholus. Spectra of active comets are about to be submitted for publication in Astronomical Journal. We examined several bright comets at high signal-to-noise ratios, including P/Schwassmann-Wachmann 1, P/Hale-Bopp, P/d'Arrest, P/Jackson-Neujmin. We detected a 2.04 μm absorption (depth ~ 8%) in P/Hale-Bopp that matches a vibrational overtone of water ice (the feature was independently noted by Davies *et al.* using the same instrument and telescope). P/Hale-Bopp's "twin" - P/SW1 - was spectrally featureless at all times in our data. In d'Arrest, we observed absorptions in the K Band that superficially match vibrations seen in complex hydrocarbons as measured by our colleague E. Cloutis. The interpretation of these features is difficult, non-unique, and not yet prepared for publication.

Publications

J. X. Luu, and D. C. Jewitt (1993), "Continued Activity in Chiron". Lenggries Workshop on Activity in Distant Comets, Eds. W. F. Huebner *et al.*, SWRI, San Antonio, TX.

D. C. Jewitt (1993), "Three Trans-Jovian Comets". Lenggries Workshop on Activity in Distant Comets, South West Research Institute, San Antonio, 64-73.

D. C. Jewitt, J. Luu and J. Chen (1993). Physical Properties of Split Comet Shoemaker-Levy 9, BAAS 25, 1042.

J. Chen and D. Jewitt (1993). On the Rate at Which Comets Split. BAAS 25, 1045.

J. Luu, D. Jewitt and E. Cloutis (1993). Near Infra-Red Spectra of Primitive Bodies. BAAS 25, 1056.

J. Chen and D. Jewitt (1994), "On The Rate At Which Comets Split", Icarus, **108**, 265-271.

J. X. Luu, D. C. Jewitt and E. Cloutis (1994). "Near Infrared Spectroscopy of Primitive Solar System Objects", Icarus, **109**, 133-144.

D. C. Jewitt (1994), "Overview of Planets and their Atmospheres", in Topics in Atmospheric and

Interstellar Physics and Chemistry, edited by C. Boutron, Les Editions de Physique, Grenoble, France, pp. 1-15.

D. C. Jewitt (1995), "From Comets to Asteroids: When Hairy Stars Go Bald", invited review for the meeting "Small Bodies and their Interactions with the Planets", held in Mariehamn, Finland, August 8-12 1994, in press.